N94- 25693

DESIGN AND DEVELOPMENT OF THE SECOND GENERATION MARS HABITAT

Prairie View A&M University
Department of Architecture
Prairie View, Texas

Dr. Ikhlas Sabouni

Roy Smith, Teaching Assistant
Steven Taylor, Brock Harrell, Earnest Crawford

Abstract

The second generation of Mars Habitat is to be utilized as an advanced permanent base for 20 crew members to live on Mars for a period of 6-12 months. It is designed to be a self-contained environment accommodating five main facilities: living, working, service, medical, and a greenhouse. The objective of the design is to create a comfortable, safe living environment. Hexamars-II and Lavapolis-II are two different concepts for the advanced Mars Habitat. The design team assumes there will be an initial habitat located near or on the site from earlier missions that satisfies the requirement for a short-term habitation for the crew to use while constructing Hexamars-II or Lavapolis-II. Prefabricated structures and materials will be shipped to the site before the long-term crew members arrival. Partial construction and preparation for the long-term habitat will be done by crew members or robotics from a previous mission. The construction of the long-term base will occur in phases. Hexamars-II consists of six sphere-shaped inflatable modules that will be partially buried below the Martian surface. The construction of each sphere will occur in ten steps. Shape charges will be used to create the crater in which the spherical structure will be placed. The interior core will be unloaded and put into place followed by the exterior structure. Foundation will be filled, interior bladder will be inflated, floor-to-floor joists connected, and sand pockets filled. Finally, the life support system and interior partitions are put in place. Each sphere consists of three levels of which the lower level will be safe haven. Particular attention is given to structural support, the dominance of internal pressure, the process of construction, and human factors.

Introduction

We are all currently living in space upon the Spaceship Earth, a self-sustaining ecosystem in orbit around the sun, which provides the energy for life.

Man has created miniature environments to support his life as he ventured into space away from the mother ship.

Skylab was America's first facility that housed astronauts for several months as they observed the dynamics of the sun. We have learned much about long-duration space flight from the experience of these missions. Skylab has since been destroyed, as its orbit decayed and it burned up in the atmosphere.

There are many reasons for the advocacy of the space movement. The exploration of the unknown, a quest for knowledge of our origin, and conquering the challenge of adventure are all inherent emotions of our species which have brought us, as a civilization, to where we are now.

Mars is the planet most similar to Earth compared to any other in the solar system. It has an atmosphere, there is an expectation of finding water at the poles, and its gravity is roughly half that of Earth's. If life existed or does exist anywhere else in the solar system, scientists argue that it would be on Mars. Mars offers the best possibility for terraforming; that is, modifying the environment to sustain life as we know it. However, there are many factors which must be addressed before we can live beyond the comforts of our planet.

During the last two years undergraduate students from the Department of Architecture at Prairie View University have been researching and designing a human settlement on Mars. The structural system and the process of construction were the main objectives of the research for this year.

Objectives

The second generation of Mars Habitat is to be utilized as an advanced permanent base for 20 crew members to live on Mars for a period of 6-12 months. It is designed to be a self-contained environment accommodating five main facilities: living, working, service, medical, and a greenhouse. The objective of the design is to create a comfortable, safe living environment. There will also be a need for the development of an oxygen plant, solar fields, Controlled Ecological Life Support System (CELSS) facilities, materials processing plant, and a nuclear power plant.

Assumptions

Hexamars-II and Lavapolis-II are two different concepts of the advanced Mars habitat. The design team assumes there will be an initial habitat located near or on the site from earlier missions, which satisfies the requirements for a short-term habitation for the crew to use while constructing Hexamars-II and Lavapolis-II. Prefabricated structures and materials will be shipped to the site before the arrival of the long-term crew members. Partial construction and preparation for the long-term habitat will be done by crew members or robotics from a previous mission. The construction of the long-term base will occur in phases.

Hexamars-II Site Location

The site location of Hexamars-II is three degrees north latitude and 99 degrees east longitude between Pavonis Mons and Ascraeus Mons. The site is congruous with the angle of space entry into Mars orbit. Another appealing factor about the site is the comfortable temperature conditions due to its location near the equator.

Materials Used for Construction

The basic materials used for the construction of Hexamars-II will consist of aluminum arches, radial floor beams, secondary bracing, and central support columns. Other major materials needed would include Kevlar-29 for the inflatable bladder, rigidized foam for the walls, partitions, and flooring, and hardened rubber or cables for the connection of the inflatable bladder. The advantage of using inflatable structures over other types is their extremely low weight to volume ratio characteristics.

Construction Considerations

For the construction of Hexamars-II, environment, time, and manpower need to be considered. The environmental factors include one-third Earth gravity, continuous solar and cosmic radiations, temperature extremes, solar wind, meteorites and dust. The use of basic construction methods, modular components, and minimal on-site fabrication will conserve precious time. With this in mind it will help to cut down on site equipment and manpower needs.

In the initial stages of construction the crew will stay in self-supporting modules from previous missions. There are two types of construction designs for Hexamars-II. The first concept uses only inflatable materials to form the sphere which consists of interior bladder and exterior rigidized foam (Figure 1). The second concept uses an inflatable sphere with aluminum I-beam arches for support (Figure 2). In the first concept, cables and a special connection device are used to connect the Kevlar-29 to the interior structures (Figures 3 and 4), while soft rubber at the ends of the floor beams is used for the same purpose in the second concept (Figure 5).

Methods of Construction

The first step of construction will use detonation charges to create the craters needed for the placement of Hexamars-II. The design team chose to use shaped charges (specially designed explosives used by the military) as detonation devices (Figure 6). There are three major advantages to using this form of explosives: the use of minimal explosives, the confinement of destruction, and the ability to penetrate deep into the regolith.

In the next phase of construction, the telescopic interior core will be unloaded and set into place inside the crater. The core will then be extended and the inflatable bladder will be pressurized (Figure 7).

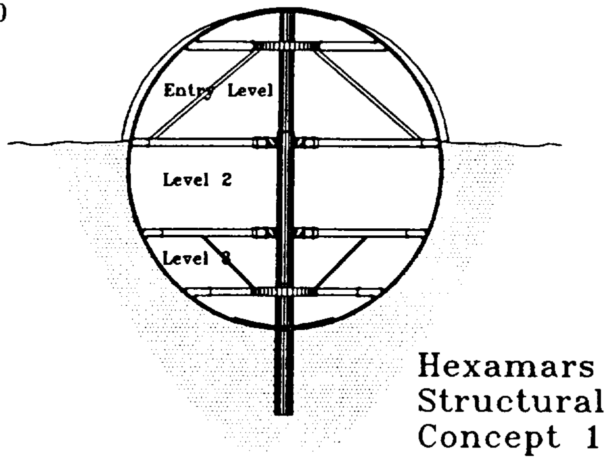


Fig. 1 Hexamars-II Structural concept 1

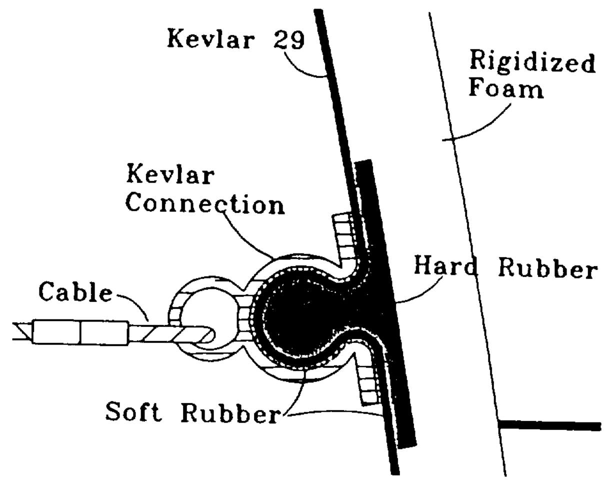


Fig. 4 Connecting device for concept 1

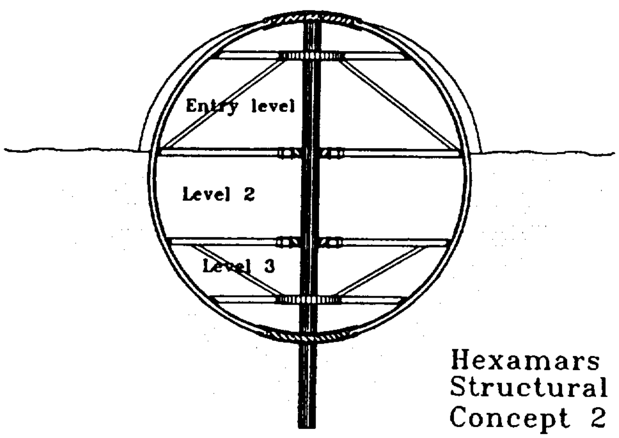


Fig. 2 Hexamars-II Structural concept 2

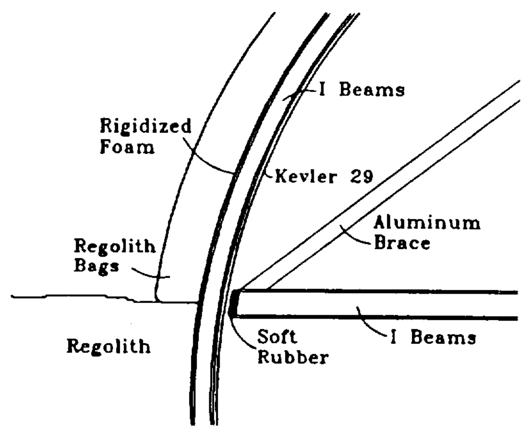


Fig. 5 Interior structure for concept 1

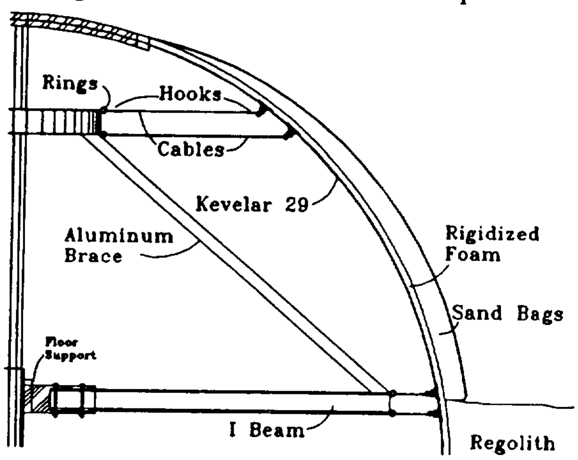


Fig. 3 Connection between Kevlar-29 and interior structures in concept 1

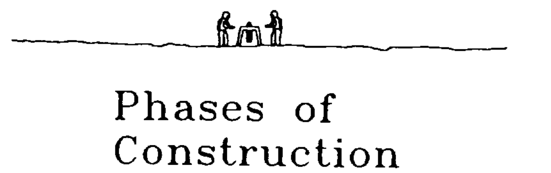


Fig. 6 Use of detonation charges

If the second concept is to be used, the exterior I-beams need to be unloaded and placed around the interior core before pressurization takes place.

Once the structure is in place and pressurized, the crater can then be filled with regolith. Then, regolith-filled bags are placed around the habitat to provide radiation protection to the interior portion of the sphere.

The last step of construction will be the placement of floor beams (Figure 8), connecting floor panels (Figure 9), interior partitions, and the installation of the life-support systems.

General Functional Relationships

The basic design of Hexamars-II aims at providing a safe and comfortable environment for the crew members. In the layout of the facility the team investigated the effects of placement of different modules and the safety risk it posed on the crew and facilities. The facilities of Hexamars-II included the habitat itself, surface vehicles, utilities, and launch and landing area.

The Habitat was broken up into six different spheres: living quarters, storage, medical, science, greenhouse, and communications. For the safety of the crew the science lab sphere was located farther away from the rest of the habitat; emergency air locks and safe havens are also located in each of the spheres. To provide circulation convenience to the crew, the living quarters are located in the central portion of the base, and the remaining facilities branch off it. Surface vehicles, which include manned rovers, tele-operated rovers, and construction equipment vehicles, are located in a construction shack near the habitat main entrance. Utilities consist of oxygen plant, nuclear power plant, and solar panel fields. These facilities are located safely away from the main base. The launching and landing facilities are located the farthest distance away from the habitat for safety reasons.

Lavapolis-II Site Location

The selection of an appropriate site is critical to the long-term success of the Mars base. An equatorial site is most economically accessed from low Mars orbit and simplifies rendezvous maneuvers. The most striking geological features, Olympus Mons, the largest volcano in the solar system, and the Colossal Valles Marinares, the colossal canyon, are located there. The site chosen for Lavapolis-II is at the base of Ceraunius Tholus, a 115-km wide, 22-km high volcano in northeast Tharsis at 24 degrees north, 97 degrees west, at the area where an impact crater has pulverized a 2-km wide channel.

The advantage of the subsurface site of a lava tube is that it is naturally protected from the hazards of meteorite impact and solar radiation with constant, relatively benign temperatures of 20 degrees Celsius. Modest site preparation inside the lava tube will prepare the tube as a receptacle for more conventional self-enclosed habitats. Accessibility, spatial distribution, and proper raw materials are needed to fulfill the mission of the base.

Precursor survey missions will define an optimal location for penetrating the roof of the lava tube. Construction will begin soon after the turn of the century. The surface features of the selected site should include the ability to sustain roadways between the launch facilities, habitat, and surface operations.

Construction Considerations

Lavapolis-II concept will provide a uniform approach to habitation on Mars inside a lava tube. The design uses a rotational hyperboloid as the primary form of the units. Aluminum framing molded into curvilinear trusses with a mechanized aluminum arch, wheeled support base truss (Figure 10), and floor supports are all contained in a structural circle (Figure 11). The inflatable portion of the structure is envisioned as an envelope made of multi-ply fabric such as Kevlar-29, a high strength aramid fiber. The inflatable portion is attached to the structural rings (Figure 12). Each cylindrical unit consists of two structural rings with an inflatable shell (Figure 13).

Component Design and Arrangement

The compact modules consist of two rotational aluminum arches supported by two ground trusses (Figure 14). The rotational arch comes manufactured with the Kevlar attached to it (Figure 15). The actual amount of space occupied while stored for transportation

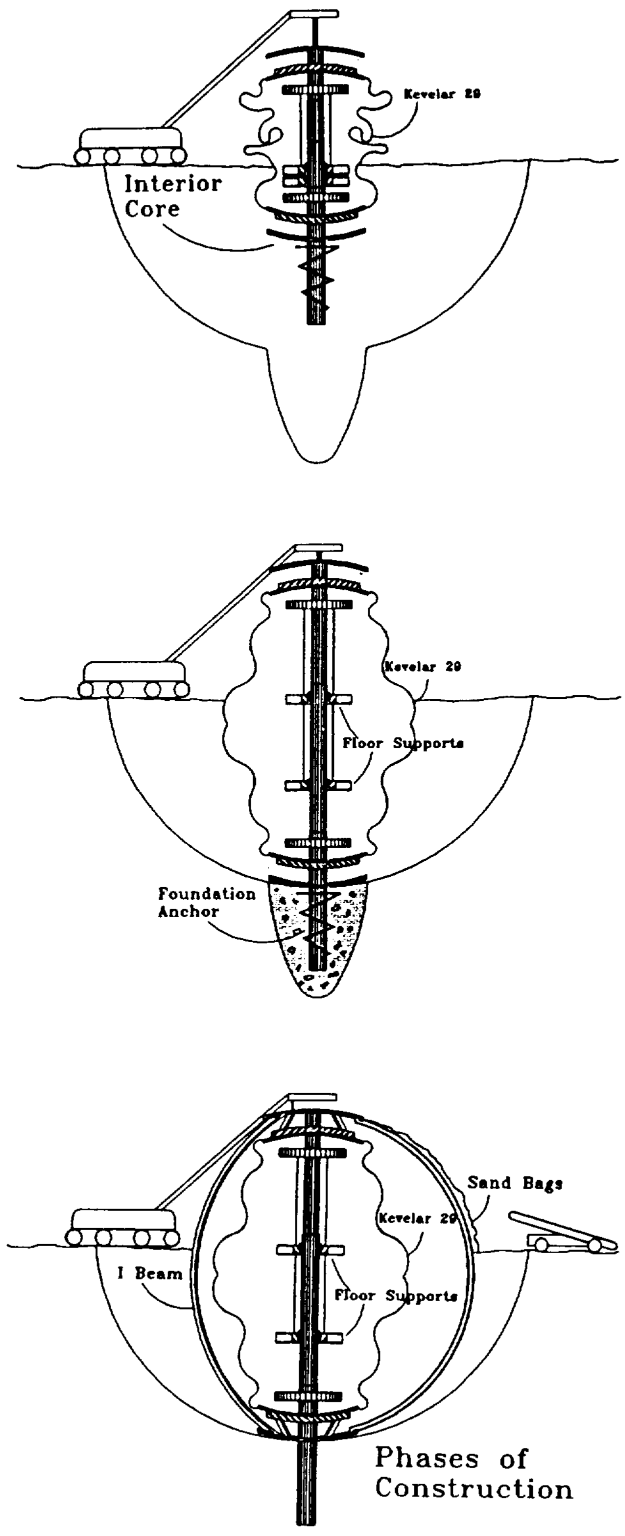


Fig. 7 Phases of construction for Hexamars-II

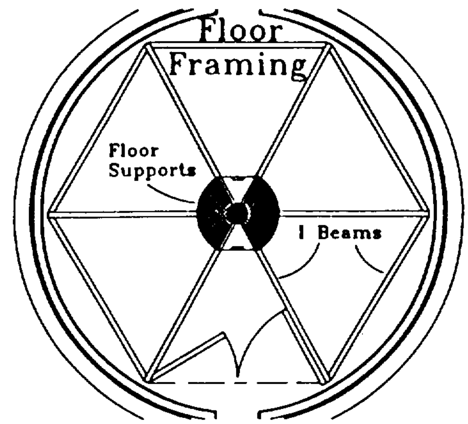


Fig. 8 Floor system

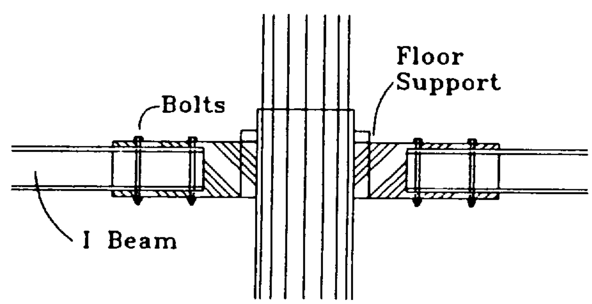


Fig. 9 Connection between floor beams and interior telescopic core

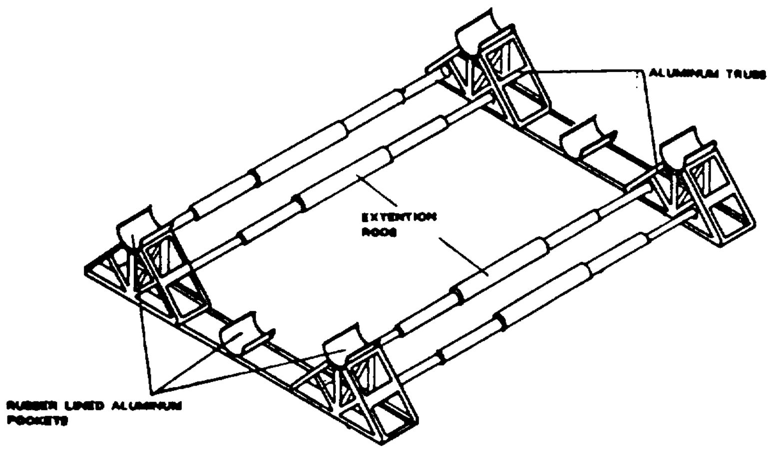


Fig. 10 Ground support components

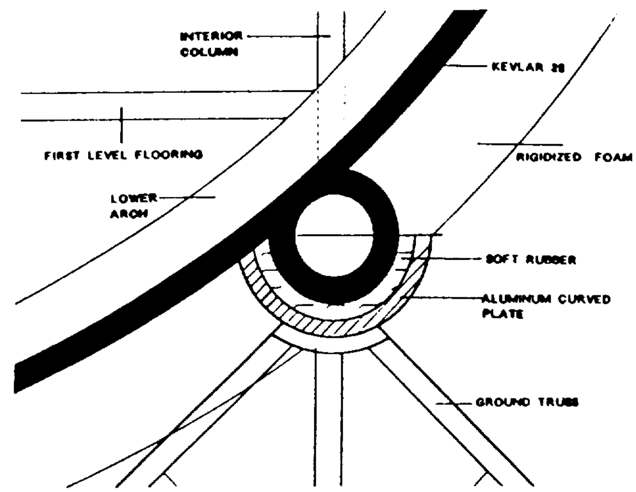


Fig. 12 Connection between inflatable cylinder and ground truss

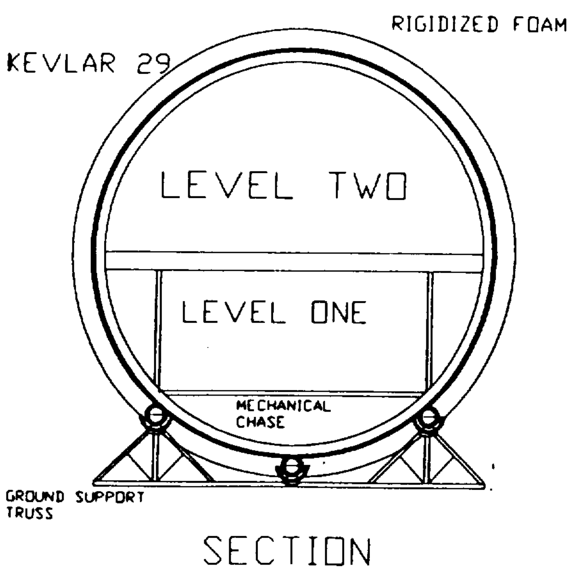


Fig. 11 Section in one of the cylindrical modules

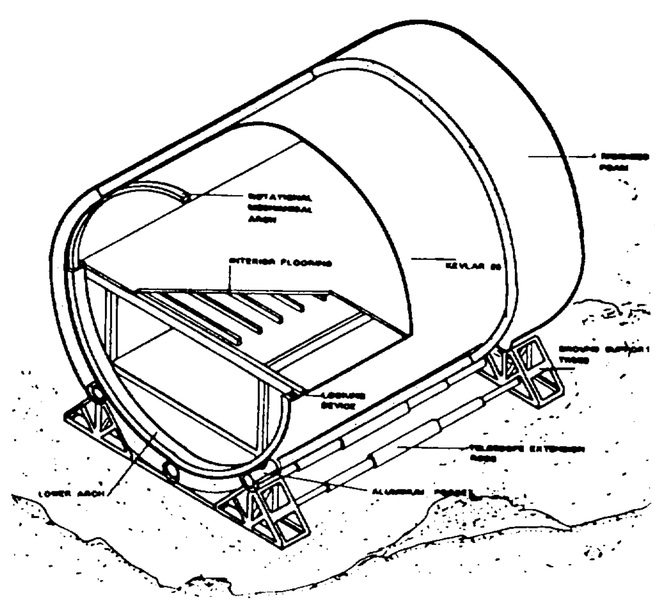


Fig. 13 One cylindrical unit

is minimum. Interior construction parts are modular and interchangeable. The components will be unloaded from the space carrier into the tube and assembled on the site.

The procedures for the first unit construction include minor excavation inside the lava tube to clear the path for construction. A crane will lower the semicircle with the attached Kevlar onto the ground truss. When the arch meets the base, the couple, which is lined with a soft durable rubber to eliminate the possible rupture of the Kevlar, is locked into place. The motorized crank is then activated to rotate the hidden arch into a locked position above the lower arch completing the two circular ends of the hyperboloid. The unit is then expanded to its maximum length.

The flexibility of the unit is achieved by alteration of components: shifting arches and a contractible brace truss. The units are adaptable to suit the requirements of up to three levels of habitat with living areas, exercise areas, health maintenance facility, crew quarters, communications, clinic labs, EVA support and maintenance, and mechanical systems.

Conclusion

Early in the research, different habitat layout concepts and different materials and technology ranging from Earthlike to spaceframe to inflatable technology were investigated, presented, and discussed with professionals from Johnson Space Center, USRA, College of Architecture at the University of Houston, and the Departments of Aerospace and Mechanical Engineering at University of Texas at Austin. The advantages and limitations of each concept were discussed during these reviews. As a result of this discussion and the constraints of using the existing technology and the need to minimize volume, weight, and construction time, the design team chose to work with inflatable structures.

This study explored the feasibility of using inflatable spheres in the design of Hexamars-II and inflatable cylinders in the design of Lavapolis-II. A third concept was also studied (Martiana) in which inflatable spheres and cylinders were used together to create spatial variety within the habitat. The same construction methods and materials of Hexamars-II and Lavapolis-II were used in the design of Martiana.

In all three concepts, a number of spheres and cylinders with air locks in between were used to create different enclosures that can be contained in case of emergency. Dual egress in each module and safe havens were two additional safety measures that were used.

The use of a number of enclosed spherical and cylindrical modules with air locks was an important factor of the design to allow for future expansions by connecting additional modules to the existing habitat without having to depressurize the existing structure. Linear and radial spatial organizations were chosen to make the expansion of the base feasible.

The form of the habitat was related to the site, the physical environment, and the quality of space and construction. The Lavapolis-II linear pattern responded to the tubular nature of the lava tube and to the geometry of the cylinders. The radial shape of Hexamars-II provided circulation convenience to the crew by designating the central sphere for living quarters and by branching all other facilities from it (Figure 16).

The design team focused more on achieving safe and simple structural systems for the base and on developing easy methods of construction with minimal on-site fabrication and manpower.

As in every design developed by an architect, engineer, or scientist, there are strengths and limitations especially with the existing technology and the limited data about the extra-terrestrial environment of Mars; this study was not any different. The advantage of this research was not only in developing an optimum design for a Mars base, but also in introducing new ideas of space design in the Department of Architecture, increasing the awareness of space design among the students, and providing an opportunity and a challenge to explore different technologies representing a departure from the traditional conventional architecture of Mother Earth.

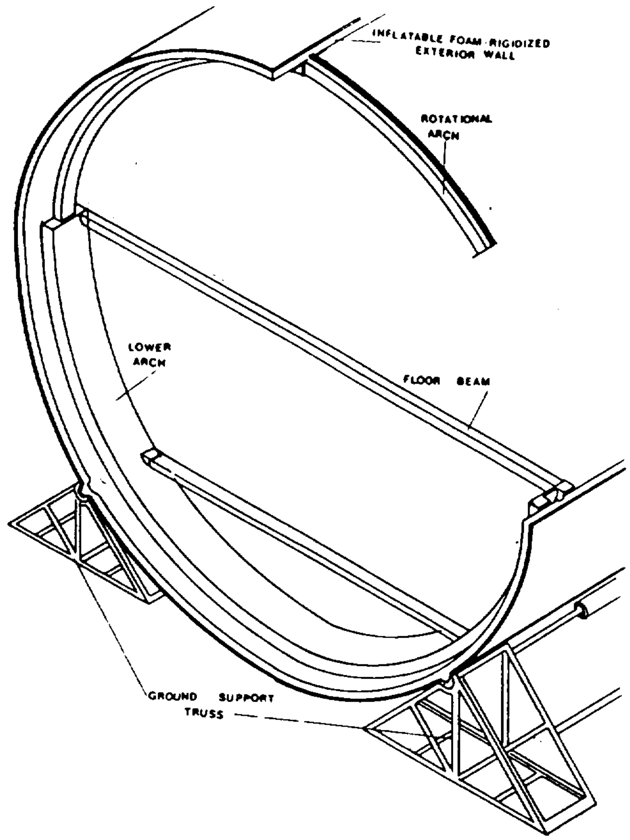


Fig. 14 Rotational and structural system

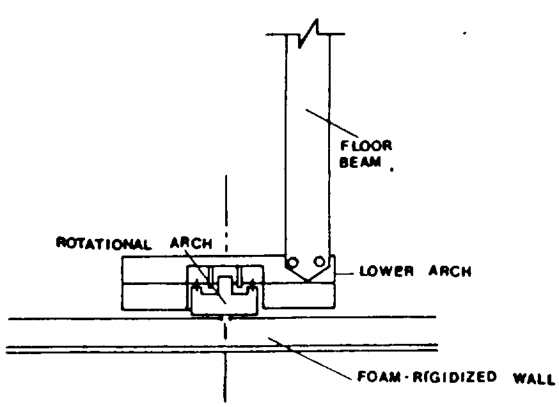
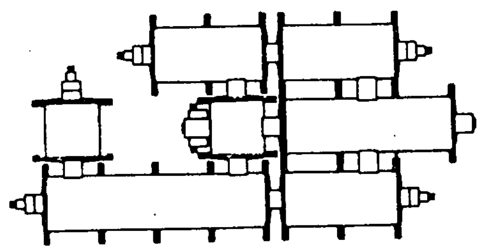
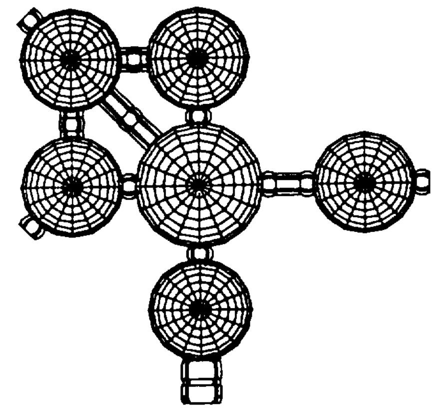


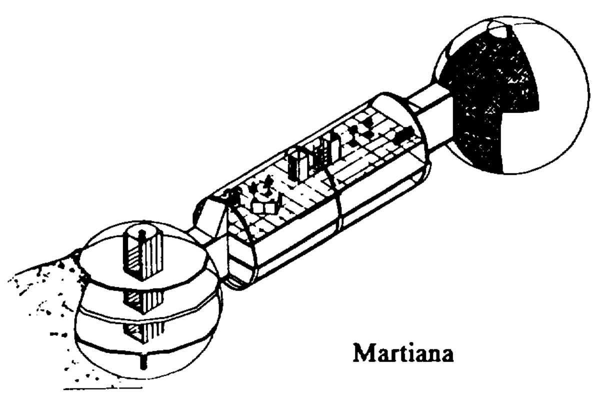
Fig. 15 Section in the structural aluminum arch



Lavapolis-II



Hexamars-II



Martiana

Fig. 16 Spatial organization of Hexamars-II, Lavapolis-II, and Martiana